ORIGINAL ARTICLE

A low cost, colour coded, hand held spring scale accurately categorises birth weight in low resource settings

L C Mullany, G L Darmstadt, P Coffey, S K Khatry, S C LeClerq, J M Tielsch

Arch Dis Child 2006;**91**:410–413. doi: 10.1136/adc.2005.088781

See end of article for authors' affiliations

Correspondence to: Dr Gary L Darmstadt, Department of International Health, E-8153, Bloomberg School of Public Health, Johns Hopkins University, 615 N. Wolfe Street, Baltimore, MD 21205-2103, USA; gdarmsta@jhsph.edu

Accepted 9 January 2006
Published Online First 7 February 2006

Aims: To determine the accuracy of a low cost, spring calibrated, hand held scale in classifying newborns into three weight categories (⩾2500 g, 2000–2499 g, <2000 g).
Methods: The test device was compared to a gold standard digital baby scale with precision to 2 g. In Sarlahi district, Nepal, 1890 newborns were eligible for the study. Measurements were collected for both the test device and the digital scale from 1820 (96.3%) newborns.
Results: The overall low birth weight (LBW) prevalence rate for the gold standard digital scale was 28.1% (511/1820). Sensitivity (93.7%) and specificity (97.6%) of the test device was high compared to LBW classifications based on digital weight measurements. Classification of infants into the <2000 g category was 5.0% and 4.7% for the gold standard and test device, respectively. Sensitivity and specificity of the test device in identifying infants <2000 g was 87.8% and 99.6%, respectively. Positive predictive values were high (>91%) for both weight categories
Conclusions: This low cost, simple-to-use device classified infants into weight categories with a high degree of consistency and accuracy that exceeds that of surrogate measures. This new device is useful for identifying and targeting life saving interventions for LBW, high risk infants in settings where infants are born in the home and conventional weighing scales are unavailable.

Approximately one sixth of all newborns globally suffer from low birth weight[1] (LBW, <2500 g), the single most important underlying risk factor for neonatal mortality.[2] In low resource settings, where most neonatal deaths occur,[3] successful management of neonates at highest risk of death depends on accurate identification and classification of newborns into birth weight dependent risk categories. Extra essential newborn care for LBW infants can reduce mortality risk by 20–40%.[4] Various cadres of village based and peripheral health facility workers, as well as families, could be trained to deliver this care,[5] yet practical implementation will require simple, inexpensive, and accurate methodologies for the classification of newborn birth weight.

Many investigators have attempted to establish cut-off points for surrogate anthropometric indicators of birth weight.[6–15] Chest circumference has generally performed better than other measures, although superior identification of LBW using mid-upper arm,[16] calf,[17 18] or thigh[19] circumference has been reported in some settings. The need to establish surrogate cut-off points independently for each population, however, has limited their use.

The Program for Appropriate Technology in Health (PATH, Seattle, USA) developed a stainless steel, hand held sling scale (BirthWeigh I) that classified infant weight into two categories (>/<2500 g). A community based validation study of 253 infants in Egypt demonstrated high sensitivity, but low specificity compared to a gold standard Salter scale, resulting in low positive predictive value (52%).[20] PATH's second generation scale (BirthWeigh II) included a plastic cylindrical handle and an indicator button that enabled both tactile and visual identification of LBW infants. A second comparative study in Egypt demonstrated that among the BirthWeigh I, II, and BebéWey (a UNICEF adaptation of BirthWeigh I) devices, the BirthWeigh II was most sensitive (>85%) and specific (99.5%) for identifying LBW infants.[21] Despite the improved performance of the BirthWeigh II scale, the cost (~US$5.00) has impeded its widespread use, and the binary classification of birth weight does not facilitate implementation of interventions requiring multiple weight category classifications, such as gentamicin treatment.

To address these limitations and to provide first level health workers with a low cost device for classifying infant birth weight, and thus, mortality risk, a refined version of the hand held scale (BirthWeigh III) was developed which classifies newborns into three categories: <2000 g, 2000–2499 g, and ⩾2500 g. This paper describes a systematic evaluation of the accuracy of this device as compared to a gold standard scale used to weigh newborn infants in Nepal.

METHODS

Study design

Data were collected within the context of a community based, cluster randomised trial of the impact of skin and umbilical cord cleansing with chlorhexidine on neonatal mortality and morbidity in Sarlahi district of Nepal, where over 95% of infants are born in the home. Infants were weighed in the home by project workers (median time 19 hours after delivery), first with the BirthWeigh III scale, then using a digital scale with precision of 2 g (Seca Digital Scale Model 727) which was standardised before each measurement using weights of 1000 and 1100 g.

The lightweight, portable BirthWeigh III scale is handheld and composed of only four main, inexpensive (e.g. tempered wire, plastic moulding based on acrylonitrile butadiene styrene polymers), easily assembled parts to assure reliability, manufacturing simplicity, and reduced cost. Full scale production cost of the device is thus likely to be less than previous scales (<US$5.00). A stair stepped indicator is fitted to the device to allow both tactile and visual delineation of three categories of weight (fig 1A). The accuracy of the precision coil spring, mounted in the device's handle, was verified during cycle testing (>10 000 cycles) to within 100 g for each category.

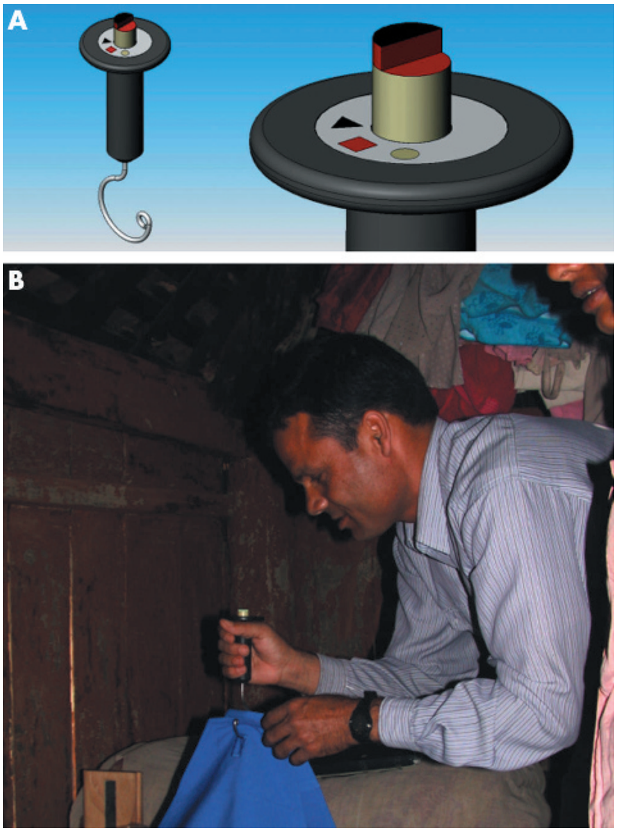

Figure 1 BirthWeigh III scale. (A) Drawing displaying the colour coded button providing tactile and visual indication of birth weight category. (B) Project worker weighing an infant with the scale. Informed consent was obtained for publication of this figure.

Training for project workers (n = 11) included a manual with written and pictorial instructions on use of the scale, and practice sessions using hand made, life size dolls of varying weights. All workers were observed directly and given constructive feedback and advice during the first week of household visits by one of the authors (LCM).

Subjects for this study were recruited consecutively among infants enrolled in the parent trial. The required sample size (n = 1070) was based on the number of infants necessary to estimate sensitivity of the device to within 5%, assuming 30% prevalence of infants <2500 g (based on data from the previous year), type I error equal to 5%, and minimum sensitivity of 70%. The final sample was slightly increased as security problems in the study area prevented timely estimates of the ongoing enrolment figures.

Workers obtained informed consent from the mother, then placed the infant in a sturdy cloth sling with two reinforced holes through which the hook at the end of the spring scale was attached. The worker raised the infant secured in the sling and observed the level of the indicator button at the top of the scale (fig 1B). If the button remained below the top level of the plastic cylinder, the worker classified the infant as having a weight of ⩾2500 g. If the first step on the indicator button could be seen or felt with the worker's thumb, the infant was classified into the 2000–2499 g category. If the entire indicator button was exposed or detected by feel, the weight class was recorded as <2000 g. The steps on the indicator button were colour and shape coded, and the recording area on the data collection form was coded with matching colours and shapes. Thus, neither literacy nor vision was required for use of the scale.

Statistical analysis
Infants with data for both the BirthWeigh III and digital scales were included in the analysis. Gold standard birth weight categories were created from the continuous weight measurements recorded using the digital scale. Sensitivity, specificity, and predictive values for the test device were estimated. All analyses were conducted using Stata version 8.0 (StataCorp., College Station, TX).

Ethical approval
This study was approved by the Nepal Health Research Council, the Committee on Human Research of the Johns Hopkins Bloomberg School of Public Health, and the PATH Human Subjects Protection Committee.

RESULTS
Between 5 March and 30 June 2004, 1820 paired measurements using the BirthWeigh III and Seca Scales were recorded (fig 2), on average 10 minutes apart. Ninety per cent of infants were measured within 72 hours and 97% within the first week of life. According to the gold standard scale, there were 1309, 421, and 90 infants in the three weight categories, ⩾2500, 2000–2499, and <2000 g, respectively, for a total LBW prevalence estimate of 28.1% (95% CI 26.0% to 30.1%). No infants ⩾2500 g were classified into the lowest weight category using the BirthWeigh III device, and a single infant of <2000 g was misclassified into the highest BirthWeigh III weight category. All other misclassifications were between adjacent categories. The sensitivity, specificity, and positive and negative predictive values of the BirthWeigh III device for identification of LBW infants and infants <2000 g are shown in table 1.

Only seven infants weighing ⩾2000 g were misclassified by the BirthWeigh III scale as <2000 g, and among these seven misclassified infants, six were within 60 g of the cut-off. Among the 11 infants <2000 g not detected as such by the BirthWeigh III device, nine were within 80 g of the cut-off. For classification of LBW, 2 of the 11 scales (#9 and #11) accounted for 21 of the 32 false negatives, and a third scale (#6) accounted for half (16/31) of the false positives.

DISCUSSION
The lightweight, portable, hand held, coil spring BirthWeigh III scale accurately classified newborns into one of three weight categories. For identification of LBW infants, the scale performed significantly better (94% sensitivity and positive predictive value) than predicted under most classification rules based on anthropometric measures. When rules have been adjusted to increase sensitivity to levels seen in this study, specificity has suffered considerably, reducing the positive predictive value of anthropometric surrogates to unsatisfactory levels.[7 8 12 22 23] In settings where infants categorised as LBW or <2000 g are referred to the next level health care centre, or are given weight dependent interventions, maintaining high specificity while still detecting a maximal proportion of at-risk infants is imperative.

The BirthWeigh III scale offers the facility to classify infants into multiple weight categories without significant loss of validity, thus extending its potential use to weight dependent interventions such as antibiotic[4] and topical emollient therapy[24 25] or vitamin A dosing.[26] The detection rate (87.8%) for infants <2000 g was higher than the overall detection rate for all LBW infants with the previous version of the scale.[20] Furthermore, this device will be more affordable than previous low cost scales, due to the emphasis during its design on simplicity and construction from inexpensive materials.

While the hand held scale operators also recorded the birth weight using the gold standard digital scale, any potential

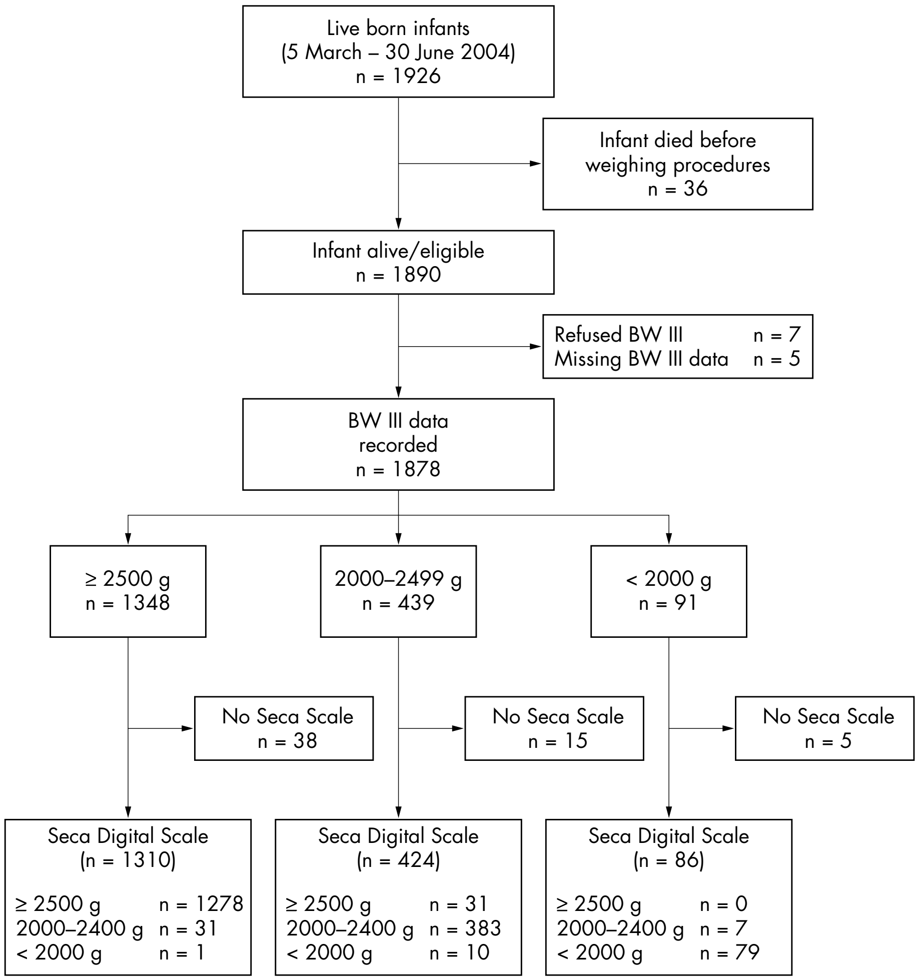

Figure 2 Study flowchart.

bias was minimised as workers recorded the test scale categorisation first, before using the gold standard digital scale to record the continuous weight measurement. The level of expertise and experience of workers in this study may not be easily replicated in other low resource settings. While this level of worker was necessary for validating the device, future investigations should describe the ease with which lesser trained individuals may utilise the scale.

Conclusion

This easily portable, durable, low cost, simple-to-use new BirthWeigh III device classified infants into mortality risk based weight categories with a high degree of consistency and accuracy, superior to results achieved with surrogate measures of birth weight or other simple, low cost scales available previously. These estimates of instrument performance indicate that this device can identify high risk infants and facilitate the targeting of potentially life saving interventions in low resource settings where deliveries occur primarily in the home and standard weighing scales are unavailable.

Table 1 Sensitivity, specificity, and predictive values for the BirthWeigh III scale relative to the digital neonatal scale for identification of LBW infants (<2500 g) and infants <2000 g

	Identification of infants <2500 g Estimate (95% CI)	Identification of infants <2000 g Estimate (95% CI)
Sensitivity	93.7 (91.3 to 95.7)	87.8 (79.2 to 93.7)
Specificity	97.6 (96.7 to 98.4)	99.6 (99.2 to 99.8)
Positive predictive value	93.9 (91.5 to 95.8)	91.9 (84.0 to 96.7)
Negative predictive value	97.6 (96.6 to 98.3)	99.4 (98.9 to 99.7)

ACKNOWLEDGEMENTS

This study was supported by grants from Save the Children-US, Saving Newborn Lives Initiative, through a grant from The Bill & Melinda Gates Foundation (810–2054); the National Institutes of Health, National Institute of Child Health and Human Development (HD44004 and HD38753), and cooperative agreements between the Johns Hopkins Bloomberg School of Public Health and the Office of Heath and Nutrition, United States Agency for International Development (USAID) (HRN-A-00-97-00015-00, GHS-A-00-03-000019-00). The funding sources played no role in the study design, collection, data analysis, writing of the report, or decision to submit the paper for publication. The BirthWeigh scale was originally designed and developed under the HealthTech programme, supported by USAID and managed by PATH. PATH redesigned the BirthWeigh scale in consultation with the investigators, and produced and provided the prototypes for this study. We thank Jessica Fleming at PATH for assistance with training of project workers in Nepal in use of the scale. Developers of the BirthWeigh III scale at PATH included Yancy Seamans, Bill Van Lew, and Glenn Austin.

Authors' affiliations

L C Mullany, J M Tielsch, Department of International Health, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD, USA
G L Darmstadt, Saving Newborn Lives, Save the Children-US (SC), 2000 M Street, NW, Suite 500, Washington DC, USA

What is already known on this topic

- Low birth weight infants must be identified in the community in order to deliver targeted interventions
- Success with cut-offs for surrogate anthropometric indicators has been limited; cut-offs may need to be established for each setting, and sensitivity and specificity measures are often inadequate

What this study adds

- This validation study demonstrates that a low cost, hand held scale designed for use in low resource settings can consistently and accurately classify newborns into one of three weight categories
- Results are superior to those achieved with surrogate measures of birth weight or previously available low cost scales and may facilitate the targeting of potentially life saving interventions in the community.

P Coffey, Program for Appropriate Technology in Health (PATH), 1455 NW Leary Way, Seattle, USA
S K Khatry, S C LeClerq, Nepal Nutrition Intervention Project, Sarlahi (NNIPS) PO Box 335, Katmandu, Nepal

Competing interests: none declared

Informed consent was obtained for publication of figure 1

REFERENCES

1 **Lawn JE**, Cousens S, Zupan J, *et al*. Four million neonatal deaths: Where? When? Why? *Lancet* 2005;**365**:891–900.
2 **Save the Children Federation**. World Health Organisation 2001 estimates. In: *Saving newborn lives, state of the world's children*. Washington, DC, 2001:1–49.
3 **United Nations Children's Fund (UNICEF)**. *The state of the world's children*. New York, 2005.
4 **Darmstadt GL**, Bhutta ZA, Cousens S, *et al*. Evidence-based, cost-effective interventions: how many newborn babies can we save? *Lancet* 2005;**365**:977–88.
5 **Bang AT**, Bang RA, Baitule SB, *et al*. Effect of home-based neonatal care and management of sepsis on neonatal mortality: field trial in rural India. *Lancet* 1999;**354**:1955–61.
6 **Bhargava SK**, Ramji S, Kumar A, *et al*. Mid-arm and chest circumferences at birth as predictors of low birth weight and neonatal mortality in the community. *BMJ* 1985;**291**:1617–19.
7 **Singh M**, Paul VK, Deorari AD, *et al*. Simple tricoloured measuring tapes for identification of low birthweight babies by community health workers. *Ann Trop Paediatr* 1988;**8**:87–91.
8 **Ramji S**, Marwah J, Satyanarayana L, *et al*. Neonatal thigh circumference as an alternative indicator of low birth weight. *Indian J Med Res* 1986;**83**:653–4.
9 **WHO Collaborative Study of Birth Weight Surrogates**. Use of a simple anthropometric measurement to predict birth weight. *Bull World Health Organ* 1993;**71**:157–63.
10 **Ngowi JA**, Redding-Lallinger R, Hirji KF. An assessment of the use of anthropometric measures for predicting low birth weight. *J Trop Pediatr* 1993;**39**:356–60.
11 **Raymond EG**, Tafari N, Troendle JF, *et al*. Development of a practical screening tool to identify preterm, low-birthweight neonates in Ethiopia. *Lancet* 1994;**344**:524–7.
12 **Arisoy AE**, Sarman G. Chest and mid-arm circumferences: identification of low birth weight newborns in Turkey. *J Trop Pediatr* 1995;**41**:34–7.
13 **Kapoor SK**, Kumar G, Anand K. Use of mid-arm and chest circumferences to predict birth weight in rural north India. *J Epidemiol Community Health* 1996;**50**:683–6.
14 **Dhar B**, Mowlah G, Nahar S, *et al*. Birth-weight status of newborns and its relationship with other anthropometric parameters in a public maternity hospital in Dhaka, Bangladesh. *J Health Popul Nutr* 2002;**20**:36–41.
15 **Naik DB**, Kulkarni AP, Aswar NR. Birth weight and anthropometry of newborns. *Indian J Pediatr* 2003;**70**:145–6.
16 **Sauerborn R**, Ouiminga RM, Kone B, *et al*. Neonatal mid-upper-arm circumference is a valid proxy for birth-weight. *Trop Med Parasitol* 1990;**41**:65–7.
17 **Samal GC**, Swain AK. Calf circumference as an alternative to birth weight for identification of low birth weight babies. *Indian Pediatr* 2001;**38**:275–7.
18 **Gupta V**, Hatwal SK, Mathur S, *et al*. Calf circumference as a predictor of low birth weight babies. *Indian Pediatr* 1996;**33**:119–21.
19 **Sharma JN**, Saxena S, Sharma U. Thigh circumference at birth as the best predictor of low birth weight babies. *Indian Pediatr* 1989;**26**:18–21.
20 **Ritenbaugh CK**, Said AK, Galal OM, *et al*. Development and evaluation of a colour-coded scale for birthweight surveillance in rural Egypt. *Int J Epidemiol* 1989;**18**(suppl 2):S54–9.
21 **Harrison G**, Galal OM, Salem SI, *et al*. *Field evaluation of three scales for identification of low birthweight infants by traditional and paraprofessional practitioners in Egypt*, Final Report submitted to PATH by the UCLA School of Public Health and the National Research Center, Cairo, December, 1992.
22 **Diamond ID**, el-Aleem AM, Ali MY, *et al*. The relationship between birth weight, and arm and chest circumference in Egypt. *J Trop Pediatr* 1991;**37**:323–6.
23 **Walraven GE**, Mkanje RJ, van Roosmalen J, *et al*. Chest circumference as a screening method for low birth weight in newborns in rural Tanzania. *Trop Geogr Med* 1994;**46**:14–16.
24 **Darmstadt GL**, Badrawi N, Law PA, *et al*. Topically applied sunflower seed oil prevents invasive bacterial infections in preterm infants in Egypt: a randomized, controlled clinical trial. *Pediatr Infect Dis J* 2004;**23**:719–25.
25 **Darmstadt GL**, Saha SK, Ahmed AS, *et al*. Effect of topical treatment with skin barrier-enhancing emollients on nosocomial infections in preterm infants in Bangladesh: a randomized controlled trial. *Lancet* 2005;**365**:1039–45.
26 **Rahmathullah L**, Tielsch JM, Thulasiraj RD, *et al*. Impact of supplementing newborn infants with vitamin A on early infant mortality: community based randomised trial in southern India. *BMJ* 2003;**327**:254–9.